

Dr. Günther stated that not only the living tortoises, but also the shells of the specimens described in the foregoing letter, with a large and highly interesting collection of other zoological objects had arrived. There had not been sufficient time to examine the whole of the contents; so that a full report must be deferred to a future meeting of the Society. At present he exhibited the largest of several specimens of *Amblyrhynchus cristatus* ( $4\frac{1}{2}$  feet long), and carapaces of the Abingdon and Albemarle Tortoises. The former was probably identical with *Testudo ephippium*; the latter came nearest to *Testudo elephantopus*. However, the skulls had not been extracted from the skins, and therefore could not yet be used in the determination of the species. Of the living examples collected by Commander Cookson at Tagus Cove, Albemarle Island, four had safely arrived in England, and were now living in the Gardens of the Society—two large ones, a pair, brought in H.M.S. 'Peterel,' and two smaller ones, probably both females, transferred by Commander Cookson to H.M.S. 'Challenger,' in which ship they arrived some weeks ago. None of the specimens put on board the 'Repulse' had arrived in England; and it was reported that all had been lost during a storm encountered by that ship on her voyage home.

Dr. Günther also mentioned on this occasion that he was now convinced that the two Aldabra Tortoises which were obtained last year, and which, owing to the excellent arrangements made at the Gardens, were doing very well, belonged to two distinct races (as pointed out in the forthcoming second part of his paper on these animals), viz. the male to *Testudo elephantina*, and the female to *T. hololissa*.

The following papers were read:—

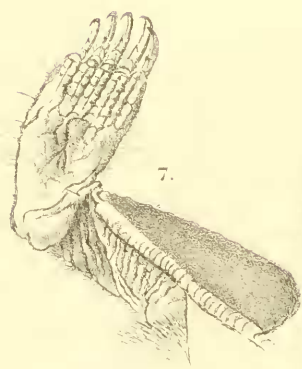
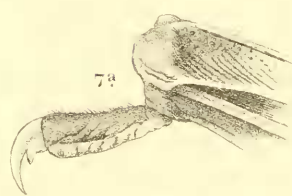
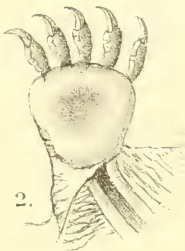
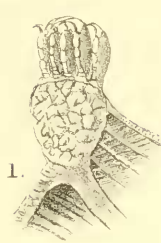
1. On peculiar Structures in the Feet of certain Species of Mammals which enable them to walk on smooth perpendicular surfaces. By G. E. DOBSON, M.A., M.B., F.L.S., &c.

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(Plate LV.)

The peculiar apparatus in the feet of Geckoes, by means of which these animals are enabled to run about securely upon smooth perpendicular surfaces, has often been referred to; and every one has observed the facility with which the common house-fly and many other species of insects can walk upon the ceiling of a room; but the occurrence of analogous climbing-organs in some species of Mammals is not generally known, or, at least, has been but imperfectly described in two instances only—namely, in *Hyrax*, and in the very remarkable species of Bat, *Thyroptera tricolor*, from Tropical America.

Several travellers have described the remarkable climbing-powers of the species of *Hyrax*, some of which live in holes in trees, upon





the smooth perpendicular trunks of which they run up and down with as much security as if their feet were provided with sharp claws. In 'The Heart of Africa'\*, Dr. Schweinfurth has given a most interesting account of the habits of one of the species of this genus. He remarks:—"Abdoo, the controller of Mvolo, was half a naturalist; as a huntsman he had done service under many Europeans, and had acquired a reputation of being a skilful stuffer of birds. He drew my particular attention to the good sport afforded by the Rock-rabbits as they crept about in tempting proximity to the gate of the Seriba. At the same time he asked if I could account for the wonderful way in which the animals managed to clamber up and down smooth rocks that were almost perpendicular. 'I can't tell,' he said, 'how it is; but when you have shot one of the creatures, and catch hold of it, it sticks to the rock with its feet in its death-struggles, as though it had grown there.' The underpart of the foot is dark and elastic as india-rubber, and has several deeply indented cushions. This arrangement, which no other Mammalia or warm-blooded animals seem to possess, enables the creature, by opening and closing the centre cleft, to throw off part of its weight, and to gain a firm hold upon the smooth surface of the stone. The toes are nothing but pads of horny skin without regular nails, the hind foot being alone furnished on the inner toe with one claw, which is sharply compressed. For some time I could not at all comprehend how, with such a plump foot, the Rock-rabbit could climb so safely over precipitous walls of granite, or even along the polished branches of the little trees in the ravines; but the mystery was solved when I tried to pick up an animal which I myself had wounded. The granite was smooth as pavement; and yet, when I seized the creature by the neck, it clung like birdlime to the ground, and required some force before it could be removed."

The very peculiar feet of *Hyrax* were first described by Bruce †; and as his description is the most complete that has been taken from the animal in its native country, I think it necessary to quote it here in full. Of the Askoko of Abyssinia (probably *H. abyssinicus*) he writes as follows:—"This curious animal is found in Ethiopia, in the caverns of the rocks, or under the great stones in the Mountain of the Sun behind the queen's palace at Koscam. It is also frequent in the deep caverns in the rocks in many other places in Abyssinia. It does not burrow or make holes as the rat and rabbit; nature having interdicted him this practice by furnishing him with feet the toes of which are perfectly round and of a soft pulpy tender substance; the fleshy parts of the toes project beyond the nails, which are rather broader than sharp, much similar to a man's nails ill grown. His hind foot is long and narrow, divided with two deep wrinkles or clefts in the middle, drawn across the centre, on each side of which the flesh rises with considerable protuberancy; and it is terminated by three claws (? toes): the middle one is the longest.

\* Vol. i. p. 385.

† 'Travels to discover the Source of the Nile in the years 1768-73,' vol. v. description of pl. 24.

The fore foot has four toes, three disposed in the same proportion as on the hind foot; the fourth, the largest of the whole, is placed lower down on the side of the foot, so that the top of it arrives no further than the bottom of the toe next to it. The sole of the foot is divided in the centre by a deep cleft like the other; and this cleft reaches down to the heel, which it nearly divides. The whole of the fore foot is very thick, fleshy and soft, and of a deep black colour, altogether void of hair, though the back or upper part of it is thickly covered, like the rest of its body, down to where the toes divide."

"The centre cleft" of Dr. Schweinfurth appears to be the groove represented in Plate LV. fig. 9, and Fig. A, which passes backwards from a slight concavity in the centre of the sole of the foot and divides the heel. I am unable to feel equally satisfied with that distinguished traveller that the simple acts of opening and closing that cleft or any cleft in the foot are sufficient to enable the animal "to throw off part of its weight and to gain a firm hold upon the smooth surface of the stone." In the ordinary condition of the foot, the central concavity is evidently not of sufficient depth or extent to cause the strong adhesion of the sole to the rock as described. I believe that the source of this remarkable adhesive power may be traced in the general structure of the extremities.

Through the kindness of Prof. W. H. Flower, I have been enabled to examine the structure of the extremities in a specimen of *Hyrax dorsalis* preserved in alcohol in the Museum of the Royal College of Surgeons; and the valuable treatises on the myology of *Hyrax capensis* by Messrs. Murie and Mivart and by Prof. J. F. Brandt have afforded me great assistance in my examination.

*Hyrax dorsalis* may be taken as a representative of that section of the genus in which the climbing-powers are, apparently, most developed, the animals of this species inhabiting holes in trees, on the vertical stems of which they run up and down with the greatest facility. The habits of the species of this section suggested the sub-generic name *Dendrohyrax*.

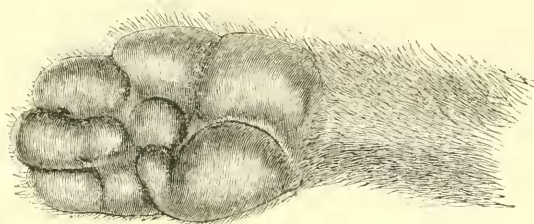
In the specimen of *Hyrax dorsalis* examined by me the soles of the feet had become quite hard and rigid from the action of the alcohol in which it was preserved; but prolonged immersion in solution of cyanide of potassium almost restored them to the original soft condition, which we know (from Bruce and Schweinfurth's descriptions made from examination of the living animal in its native country) is the normal state of the sole of the foot during life.

In all climbing four-footed animals the anterior extremities perform by far the most important part in maintaining their hold; and the species of *Hyrax* form no exception to this rule.

The fore foot has five toes (one, the pollex, being rudimentary and concealed beneath the skin); the hind foot three only (Plate LV. fig. 9). The toes are united as far as the bases of the terminal phalanges; the outer toe of the fore foot is united along its whole length. The nails are flat and short; and beyond them the soft extremities of the toes project, except in the case of the inner toe of the hind foot,

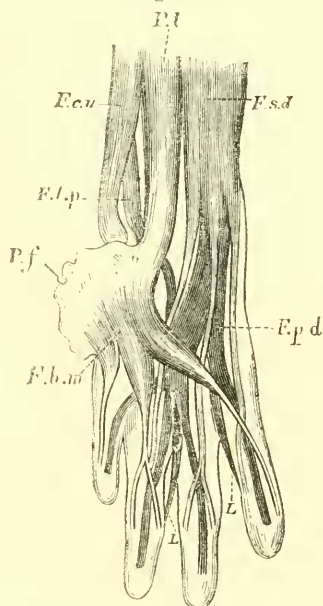
which is armed with a small blunt hoof-like claw placed on the upper and outer side of the toe, next the middle toe, its projecting outer margin being received into a deep groove in the side of the middle toe when the toes are approximated (Plate LV. fig. 9, and Fig. A).

Fig. A.

Sole of foot of *Hyrax dorsalis*.

The transverse clefts in the sole of the foot, described by Bruce and Schweinfurth (and shown in fig. A), correspond simply to

Fig. B.



Flexor muscles and tendons of the fore foot.

*P.l.*, palmaris longus; *E.c.u.*, flexor carpi ulnaris; *F.s.d.*, flexor sublimis digitorum; *E.p.d.*, flexor profundus digitorum; *F.l.p.*, flexor longus pollicis; *P.f.*, palmar fascia; *F.b.m.*, flexor brevis manus; *L.*, lumbricales.

the lines of flexion indicating the position of the joints of the toes, and the longitudinal cleft dividing the heel to the groove along which the tendons of the flexor muscles enter the sole of the foot; but the great depth and extent of these grooves evidently allow of very free motion in the sole during flexion and adduction, the importance of which will be seen when we investigate the mechanism on which the adhesive power of the foot depends.

There is nothing therefore in the structure of the sole of the foot alone which can explain the extraordinary power of clinging to smooth surfaces which we know the species of *Hyrax* possess.

In dissecting the flexor muscles of the forearm the comparatively very large size of the *palmaris longus* is particularly noticeable (Fig. B, *P.l.*). This muscle, arising from the internal condyle of the humerus and from the intermuscular fascia, forms a broad and strong tendon which, passing into the sole of the foot, spreads out into the palmar fascia, which contains a fibro-cartilaginous disk. From the superficial and deep palmar fascia, and from this fibro-cartilaginous disk, arises a very peculiar muscle (first described by Messrs. Murie and Mivart\*), the *flexor brevis manus* (Fig. B, *F.b.m.*), which is inserted by three tendons into the second, fourth, and fifth toes. The tendon going to the second, or inner toe, is inserted on the inner side of the tendon of the *flexor profundus*, while that going to the fifth or outer toe is inserted on the outer side of the tendon of the same muscle; the middle tendon forms, with the corresponding tendon of the *flexor sublimis*, the perforated tendon of the fourth toe; and as this toe is so much longer than the second and fifth toes, the positions of the insertions of the three tendons of the *flexor brevis manus* occupy nearly the same line across the foot.

If we take a line drawn along the middle of the fore foot from the centre of the carpus to the extremity of the third toe as the centre line of the foot, we find the insertions of the *flexor brevis manus* on either side of this line, two of the three tendons being inserted at points on opposite sides of the foot furthest from the centre. The action of this muscle must therefore be, not only to flex the outer and inner toes, but also to rotate them slightly and draw inwards both sides of the foot towards the centre line. In this action the tendency to cup the sole of the foot is evident. Further, as the *flexor brevis manus* arises from the palmar fascia, it follows that this muscle can only act effectively when its point of origin is fixed; and this is accomplished by the action of the strong *palmaris longus*, which, as we have seen, terminates in the palmar fascia. In the co-ordinate action of these two muscles on such a foot provided with a soft elastic sole and united toes we have, I believe, all that is necessary to produce the remarkable power of adhesion of the foot to any smooth surface on which it may be placed, which has been observed in most species of *Hyrax*.

The *palmaris longus*, in fixing the palmar fascia, removes the

\* *L. c.* p. 341. Messrs. Murie and Mivart (with the sanction of the Council of the Society) have kindly permitted me to make use of one of the wood blocks (Fig. B) from which the illustrations accompanying their paper were printed.

pressure of the centre of the sole of the fore foot, while the soft elastic sides and heel are in close contact with the surface on which the animal is walking; at the same time the *flexor brevis manus* elevates the greater part of the anterior half of the sole by pressing the extremities and sides of the outer and inner toes downwards and also drawing them towards the centre line of the foot, thus producing a condition of the sole of the foot analogous to the sucking-cup of a cephalopod.

In the hinder extremities the same conditions are fulfilled, though evidently much less effectively. The homologue of the *palmaris*, the *plantaris*, is also very large, and arises from the external condyle of the femur; and its tendon similarly passes into the sole of the foot to form the plantar fascia from which the *flexor brevis digitorum* arises as the *flexor brevis manus* in the fore foot.

The softness and elasticity of the sole of the foot (described by Bruce and Schweinfurth) permit of nice adaptation to slightly uneven surfaces, and render the suction action, by which cohesion is maintained, possible. As it appeared evident to me that this soft condition of the sole must depend not only on large development of the subcutaneous areolar tissue, but also on a permanently moist state maintained by the secretions of numerous sudorific glands, I was not surprised to find, on examining several horizontal and vertical sections of the integument of the sole of the foot, that the sudorific glands were exceedingly numerous, at least fifteen times as numerous in a given space as in the sole of the human foot, amounting to 40,000 in the square inch\*.

With such an enormous number of sudorific glands the sole of the foot is doubtless kept constantly moist, and in the most favourable condition for adhering to smooth or slightly uneven surfaces, when it is converted into a kind of suction disk by the action of the muscles as described above.

It might appear strange that, with such a soft sole to the foot, the animal could run with impunity over hard and occasionally angular surfaces; but I find that the sole is everywhere protected by a deep layer of epithelium, in no place less than  $\frac{1}{2}$  of an inch in thickness. The importance of the great number of sudorific glands is here again apparent; for, with such a deep layer of epithelium, the sole of the foot would soon become quite horny from the effects of constant pressure, were it not kept constantly moist by an abundant glandular secretion †.

In the very remarkable species of Bat, *Thyroptera tricolor*, first described by Spix ‡, we find the only known instance (in Mammalia)

\* I have arrived at this calculation from observing that sometimes five, but more frequently four of the openings of the sudorific ducts were contained within a measured space equal to the square of  $\frac{1}{100}$  of an inch. If, therefore, we assume four as the average number in this space, it follows that exactly 40,000 are contained within a square inch.

† The significance of the *retia mirabilia* in the extremities of *Hyrax*, first described by Hyrtl, will be at once understood when we consider how necessary it is to maintain a constant vascular condition of the foot in order to keep up the abundant secretion poured forth by the numerous sudorific glands.

‡ Simiar. et Vespert. Brasil. 1823, p. 61, pl. xxxvi. fig. ix.



of the presence of prehensile organs resembling the sucking-disks of Cephalopoda. On the inferior surface of the thumb, from the base of the first phalanx, and from the sides of the metacarpo-phalangeal joint, corresponding to the position of the ball of the thumb in other Bats, arises by a short peduncle a circular hollow suctorial disk about one tenth of an inch in diameter (Plate LV. fig. 5, enlarged). On the sole of the foot a similar but considerably smaller disk (fig. 6) is placed, not in the same relative position, however, as on the thumb; for it covers the metatarsal bones, not the bases of the first phalanges of the toes.

In a paper published in the 'Boletin revista de la Universidad de Madrid,' by Señor Jimenez de la Espada, a member of the Spanish Expedition to explore the natural productions and physical conditions of South America, the author relates his observations on the habits of this species, and describes the sucking-cups. I have not been able to procure a copy of this paper; but fortunately a full abstract of the part relating to *Thyroptera tricolor* is given in the 'Zoological Record' for 1870, as follows:—

"The sucking-cups consist of a coriaceous disk; they are little hemispheres, hollow, flexible, and extremely movable, on the first phalanges of the thumbs of the wings and near the heels on the soles of the feet. They were used by the animal to fasten itself to the fingers as it tried to bite, producing the same feeling as a key or thimble when applied to the tongue after sucking out the air. These cups are deep, membranaceous on the edge, fleshy in the centre, those on the wings larger than those on the feet. The muscular arrangement is such as to allow the animal to vary the diameter of the organ; and by their means the animals attached themselves to the sides of the box in which they were kept, although, when sleeping, they suspended themselves by the claws like other Bats."

With the latter part of the above statement, referring to a muscular arrangement in a sucking-disk, I am quite unable to agree. Microscopical sections of the disk made in every direction failed to exhibit the slightest trace of muscular fibre; and I believe that the animal does not possess the power of varying the diameter of the organ by direct muscular agency. Indeed the presence of a muscular arrangement in the sucking-disk of *Thyroptera tricolor*, such as Señor Jimenez de la Espada refers to, would be a most remarkable anomaly; for this species would possess special muscles of which not the slightest homologue could be found in any other vertebrate animal. But nature does not form complicated organs where simple ones are equally or sufficiently effective. The remarkable sucking-cups of *Thyroptera* are evidently but highly differentiated conditions of the integuments and superficial fascia of the balls of the thumbs and soles of the feet. This is shown by their position, by their structure, and by the presence in other Bats of analogous conditions of the same parts, which must be also considered homologous.

In *Vesperugo nanus*, Ptrs., *V. tylopus*, Dobson (Plate LV. figs. 1 & 3), and especially in *V. pachypus*, Temm. (fig. 2), the sole of the foot is very broad, slightly concave, and almost circular in outline, so

much expanded as to project considerably beneath the toes. The toes are very short and have feeble claws. The ball of the thumb covering the metacarpo-phalangeal joint is also much expanded and flattened. This remarkable condition of the sole of the foot and of the thumb is seen, on examination by the microscope, to be due to the great development of the integument and areolar tissue. In these Bats the feet are undoubtedly adhesive, enabling them to walk on smooth hard surfaces, where the claws could afford but slight aid in progression; but the adhesive power is evidently much inferior to that possessed by *Thyroptera*; nevertheless the difference in structure between the comparatively simple adhesive sole of the foot and thumb of *V. pachypus*, and the highly differentiated sucking-cups of *T. tricolor* is one of degree only.

The walls of each cup are composed, from without inwards, 1, of skin (continuous with the integument of the thumb); 2, of a middle layer of connective tissue with cartilage cells and glandular tissue; and, 3, of a thin epithelial layer lining the concavity of the cup, having on its surface the openings of glands, which are most abundant near the margin of the disk. The middle layer at the base of the cup, for a short distance around the point of its connexion with the short pedicle which attaches it to the thumb, consists almost entirely of cartilage cells, which soon become considerably thinned out and replaced by another form of connective tissue. This connective tissue, which forms the greater part of the walls of the suction disk, lying (as already described) between an outer and inner\* layer of integument, appears to consist of two layers, that lying next the external integument being very dense and having a few cartilage cells, while the inner layer lying next the thin epidermis lining the cup consists of rather broad fibres radiating from the cartilaginous base of the cup towards its circumference, and which cause a corresponding radiating appearance in the cuticle lining the concavity of the cup (see Plate LV. fig. 5).

These radiating fibres no doubt suggested to Señor Jimenez de la Espada the idea of a muscular apparatus; but, as I have already remarked, no trace of muscular tissue can be detected in them or in any other part of the disk. They are about  $\frac{1}{100}$  of an inch in diameter and extend from the cartilaginous base of the disk outwards to within a short distance from its free margin, being separated from each other by a thin layer of connective tissue derived from the outer part of the middle layer. Examined under high powers and with an immersion-lens, they appear solid and almost structureless †. Although they do not present the characters of ordinary elastic

\* The terms "outer" and "inner," used with reference to the suction disk, refer to its convex and concave surfaces, which I here, for convenience, consider its outer and inner sides respectively.

† Prof. Turner has kindly examined these radiating fibres for me; he says:—"With careful focusing I think that I can recognize traces of structure in each fibre; there are appearances of very minute elongated nuclei, such as one seen in tendon. . . . I am disposed, on the whole, to regard them as a modification of connective tissue, though not elastic." Prof. Turner means by this that they do not present the characters of what is commonly known as elastic tissue.